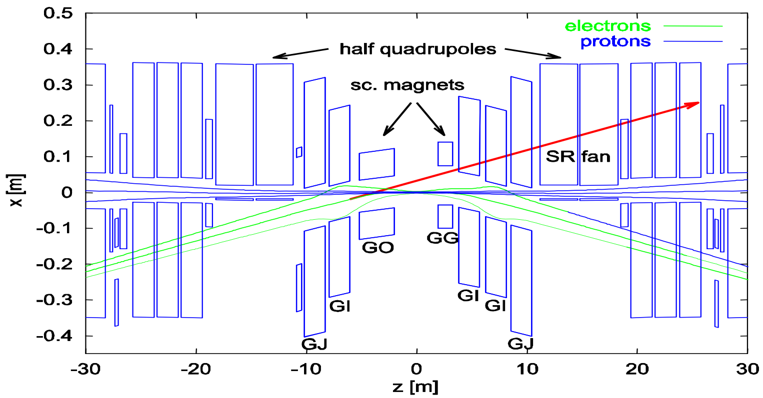
Electroweak Studies in e^-p DIS scattering with polarised electrons

Main aim of this analysis

- **Polarisation dependence of neutral current cross sections**
- **Asymmetry parameter A^-**
- **Extraction of the structure function xF_3**

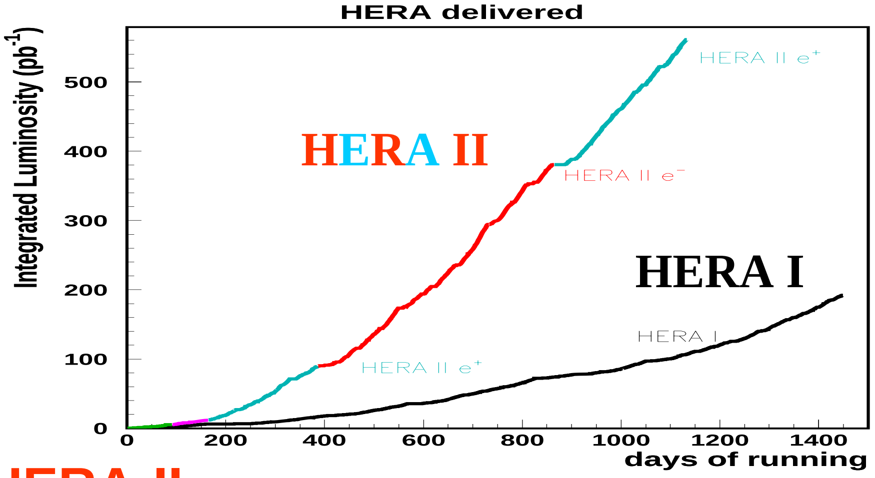
HERA Upgrade – HERA II

Enhanced Luminosity : most precise measurement of NC cross section at small λ



“mini-beta” final focusing magnets closer to detector

improvement in the vacuum + synchrotron background problems resolved

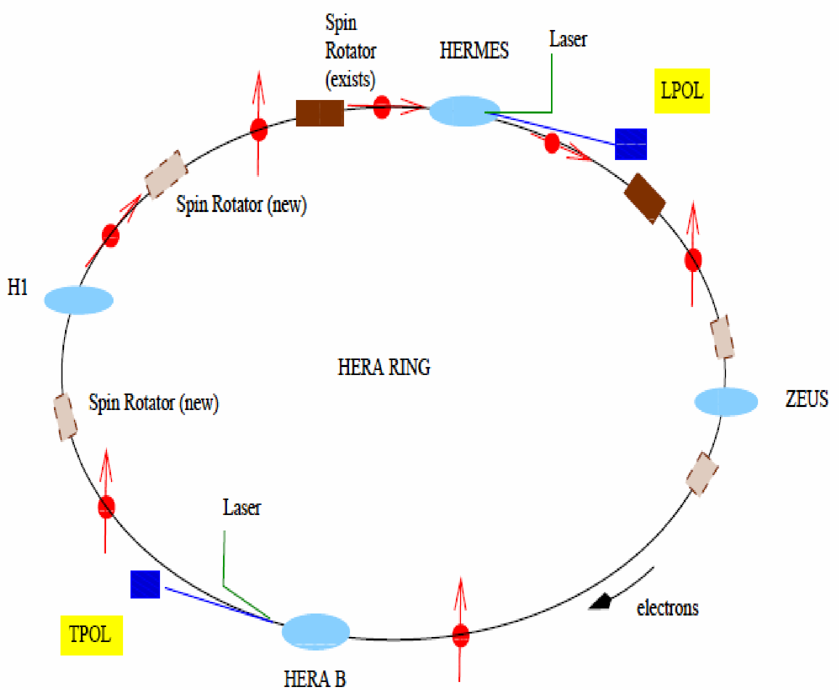


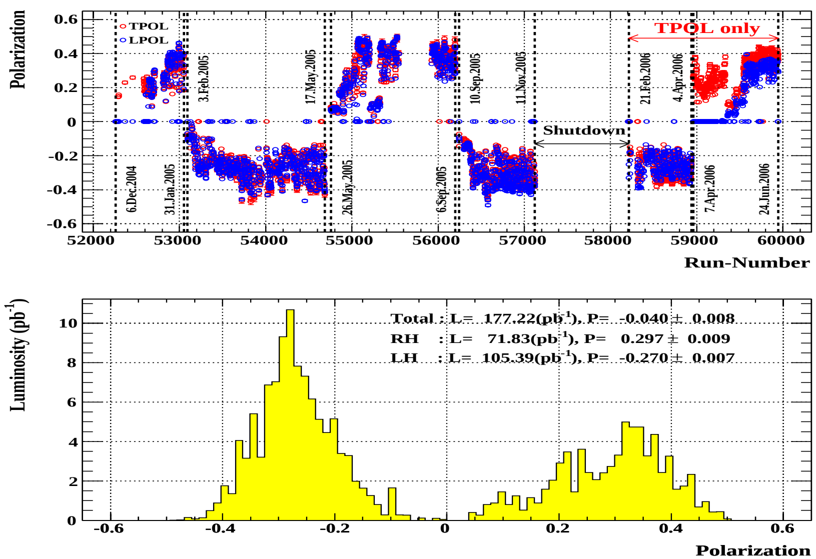
- Change in slope
- Higher luminosity
  - access higher Q^2

	HERA-I	HERA-II
e-	~27 pb^{-1}	~290 pb^{-1} ←
e+	~165 pb^{-1}	~270 pb^{-1}

HERA II Upgrade

Study interactions of longitudinally polarised leptons + quarks at ElectroWeak scales





ZEUS

Natural transverse polarsiation
- **Sokolov-Turnov effect**

Spin rotator before/after ZEUS
- **Longitudinal polarisation**

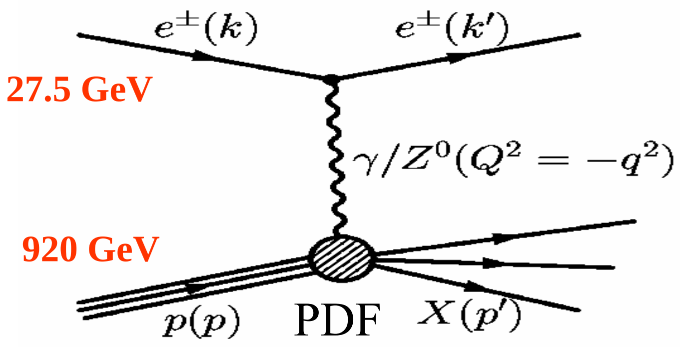
$$P_e = \frac{N_R - N_L}{N_R + N_L}$$

e^- (R) ~ 71.8 pb-1 @ Pe ~ +29.7 %
e^- (L) ~ 105.4 pb-1 @ Pe ~ -27.0 %

NC process and kinematic variables

eq x PDF = EW x QCD

e p ⟶ e'X



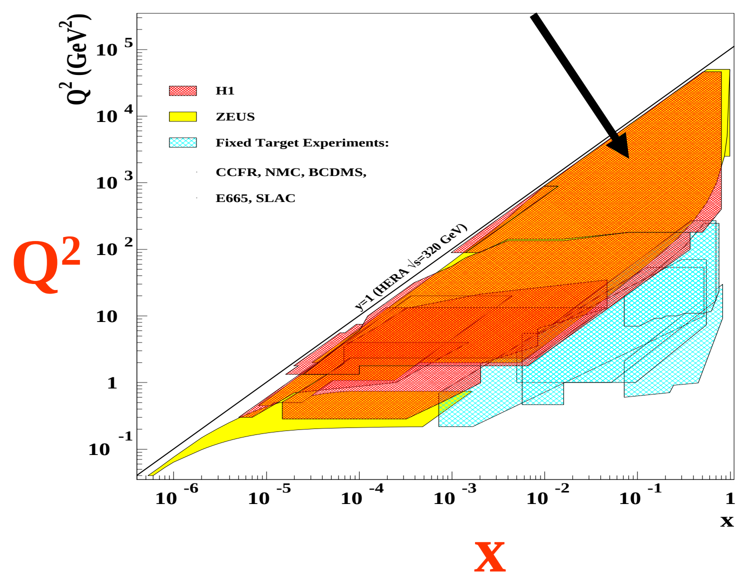
CM energy: $\sqrt{s} = 318$ GeV
$\lambda \sim 10^{-18}$ m

$$Q^2 = -q^2 = -(k-k')^2$$: virtuality of exchanged boson

$$x = \frac{Q^2}{2p \cdot q}$$: Bjorken x

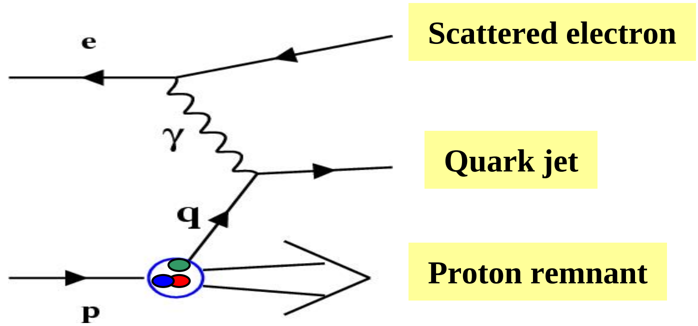
$$y = \frac{p \cdot q}{p \cdot k}$$: inelasticity

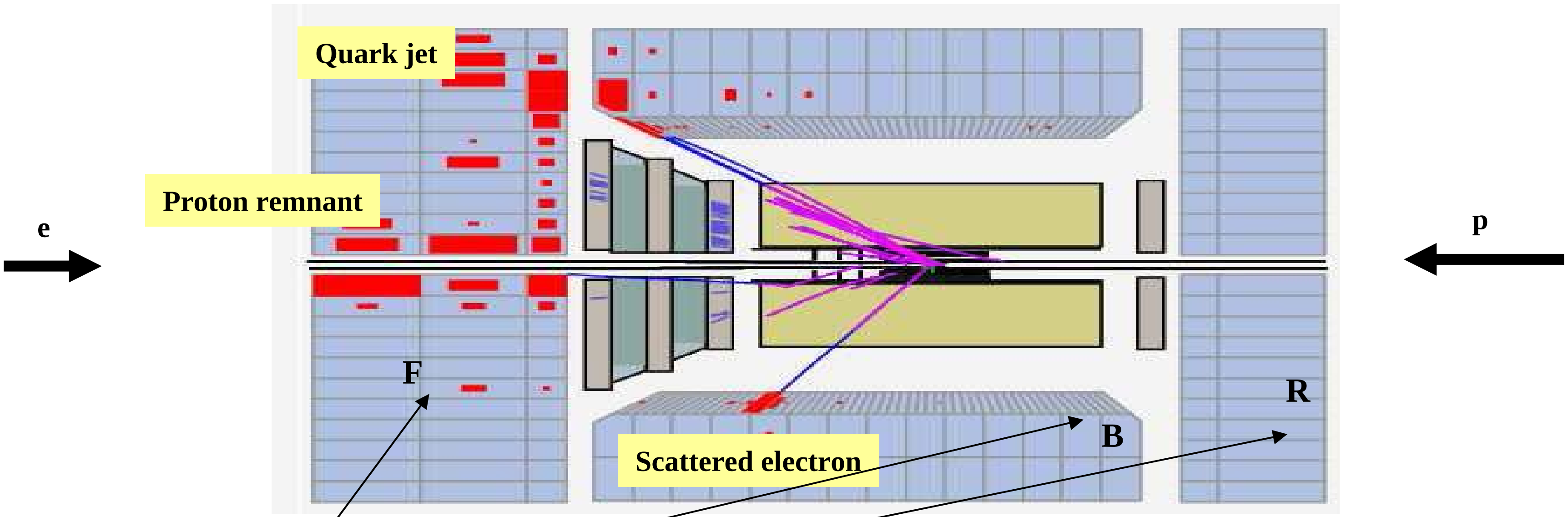
$$Q^2 = sxy = 2E_e E_e^{'}(1+\cos\theta_e)$$



- Need energy of scattered electron
- angle of this electron
- and/or angle of the hadronic jet

What does a NC event look like in the ZEUS detector?





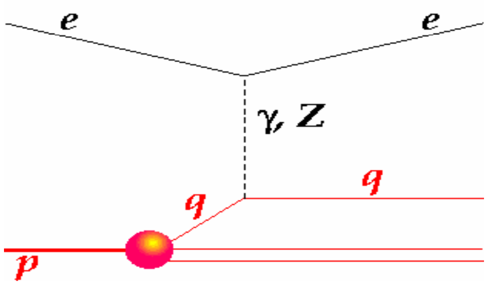
Calorimeters + **Tracking chambers**

electron: $E_e > 10$ GeV and θ_e
isolated from quark jet γ_h

beam gas, cosmic, PhP rejection

Cross section for unpolarised NC scattering

$$Y_{\pm} = 1 \pm (1-y)^2$$



- in terms of three "structure functions"

F_2, F_3, F_L

$$\frac{d^2\sigma_{NC}^{e^\pm p}}{dxdQ^2} = \frac{2\pi\alpha^2}{xQ^4} \cdot \left[Y_+ \cdot F_2(x,Q^2) \mp Y_- \cdot xF_3(x,Q^2) - y^2 F_L(x,Q^2) \right]$$

Sizeable at high y

$$F_2^{NC} = x\sum_f A_f(Q^2)[q(x,Q^2) + \bar{q}(x,Q^2)]$$

$$xF_3^{NC} = x\sum_f B_f(Q^2)[q(x,Q^2) - \bar{q}(x,Q^2)]$$

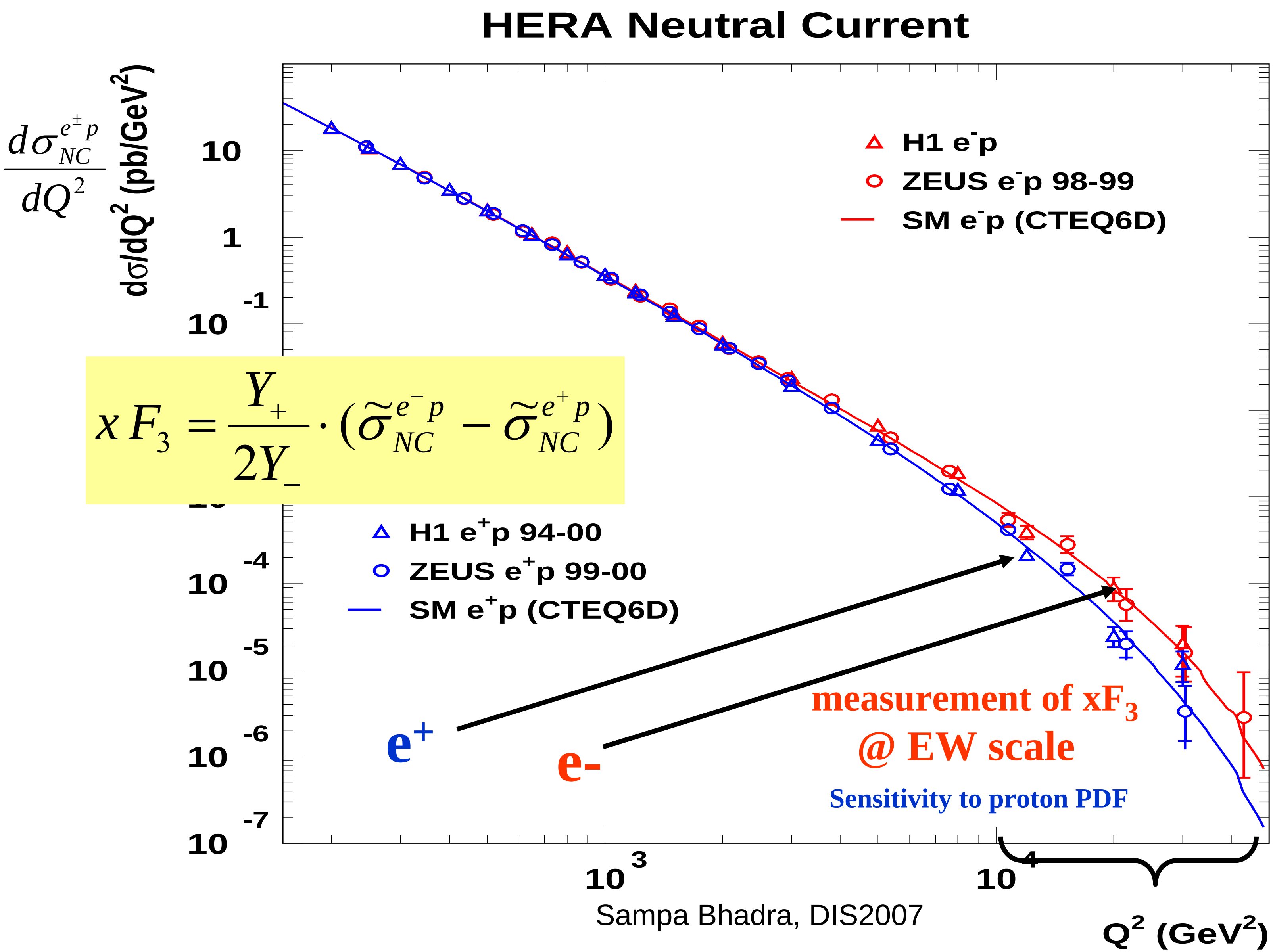
Sensitivity to the valence quark distribution

$$\tilde{\sigma}_{NC}^{\pm} = \frac{xQ^4}{2\pi\alpha^2} \frac{1}{Y_+} \frac{d^2\sigma_{NC}^{e^\pm p}}{dxdQ^2}$$

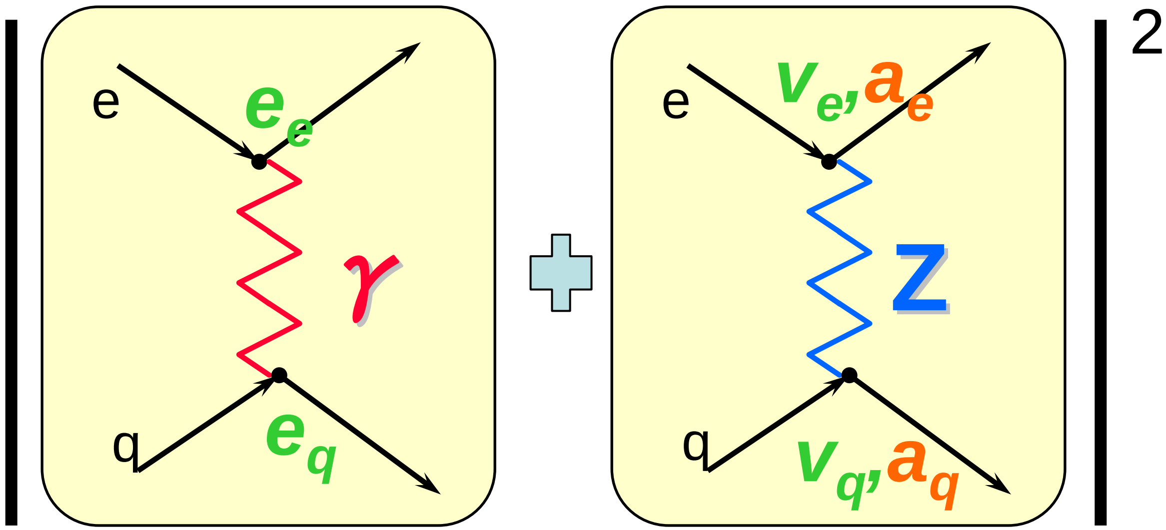
Sign of xF_3 term changes: e^+ vs. e^- →

HERA I: NC Unpolarised data: e^- and e^+ scattering off protons

$$xF_3 = \frac{Y_+}{2Y_-} \cdot \left(\tilde{\sigma}_{NC}^{e^- p} - \tilde{\sigma}_{NC}^{e^+ p}\right)$$



Polarisation effects in NC - Structure functions



	v	a
e	-0.04	-0.5
u	0.196	0.5
d	-0.346	-0.5

v_e terms dropped

Unpolarised: Extract $xF_3^{\gamma Z}$

Polarised: Extract $F_2^{\gamma Z}$

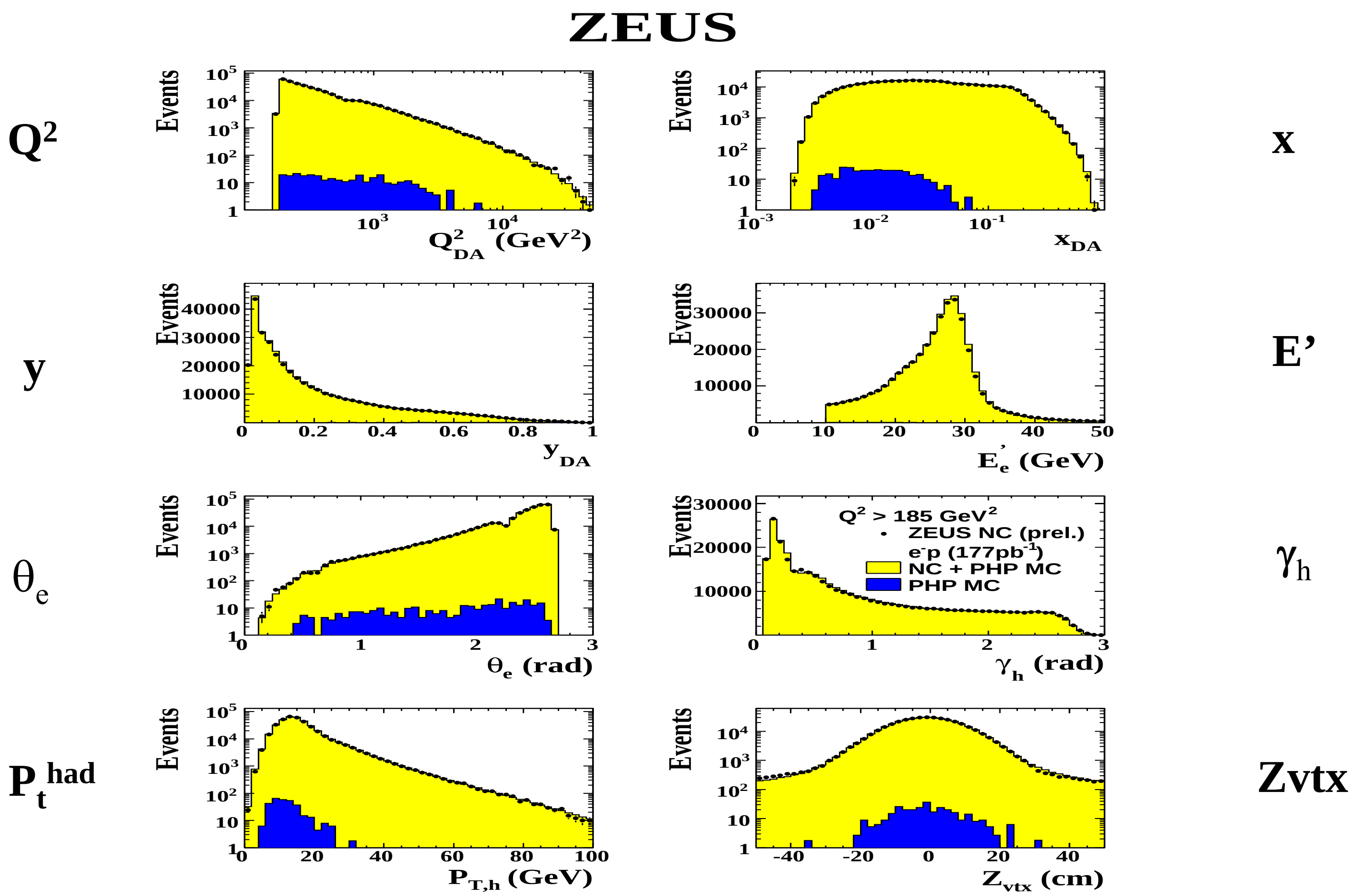
$$\chi_Z = \frac{1}{\sin^2 2\theta_w}\left(\frac{Q^2}{Q^2 + M_Z^2}\right)$$

$$F_2(x,Q^2) = F_2^{\gamma} + (-v_e + P_e a_e)\chi_Z F_2^{\gamma Z} + (v_e^2 + a_e^2 - 2P_e v_e a_e)\chi_Z^2 F_2^Z$$

$$xF_3(x,Q^2) = -(a_e - P_e v_e)\chi_Z xF_3^{\gamma Z} + (2v_e a_e - P_e(v_e^2 + a_e^2))\chi_Z^2 xF_3^Z$$

dominates

Comparisons with M.C. simulation - ARIADNE (CDM)



Black: Data
Yellow-ARIADNE+ PhP
Blue: Photoproduction

Fairly good agreement ….
unfold data to get cross sections

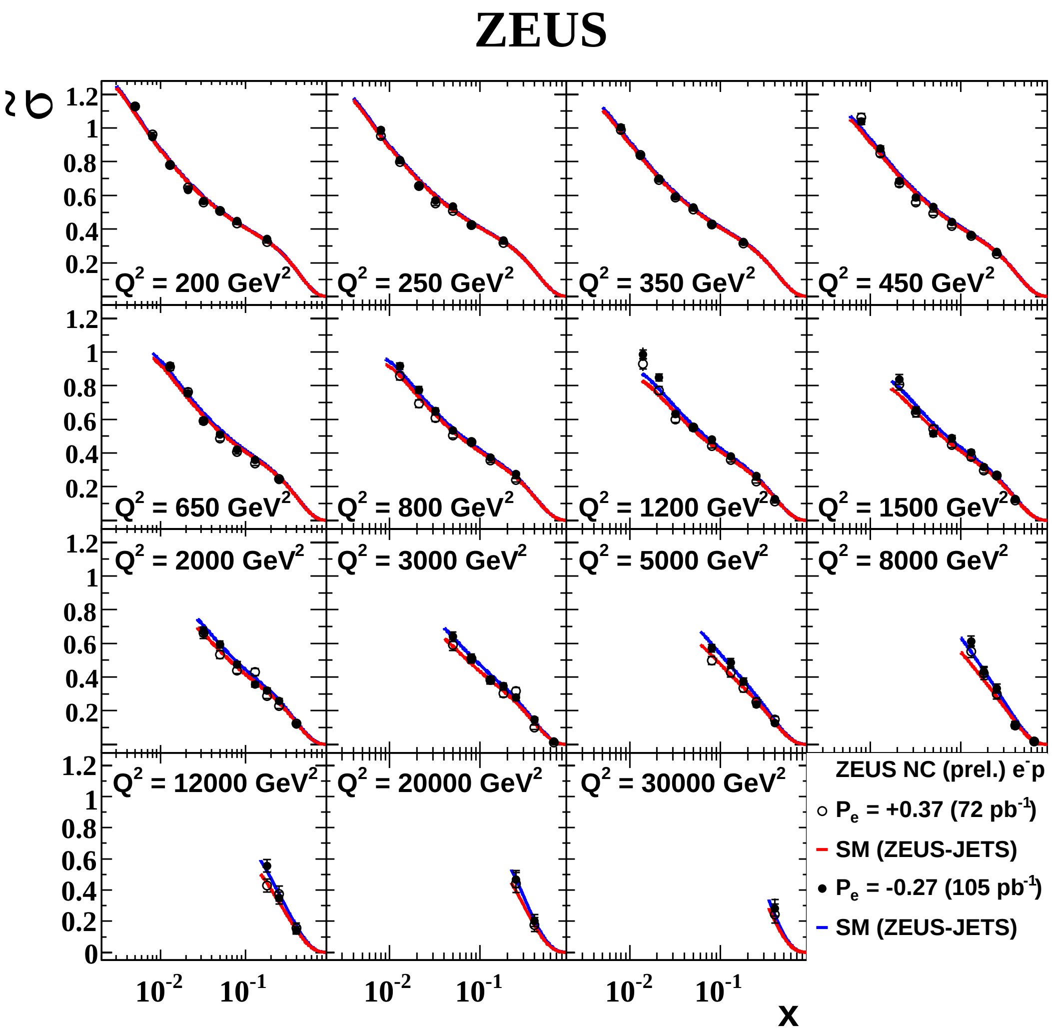
Systematics

Check selection criteria – electron energy, energy scale, etc.

- The uncertainty on the cross section measurements due to the imperfect reconstruction of the scattered electron and hadronic system and backgrounds are estimated using the MC

-Controlled to a few % level over large kinematic range but can be as high as ~8% at high-Q^2 and high-x where the statistical error dominates.

Reduced cross section for polarised electrons



$$\tilde{\sigma}^{\pm} = F_2\left(x, Q^2\right) \mp \frac{Y_-}{Y_+} \cdot x F_3\left(x, Q^2\right)$$

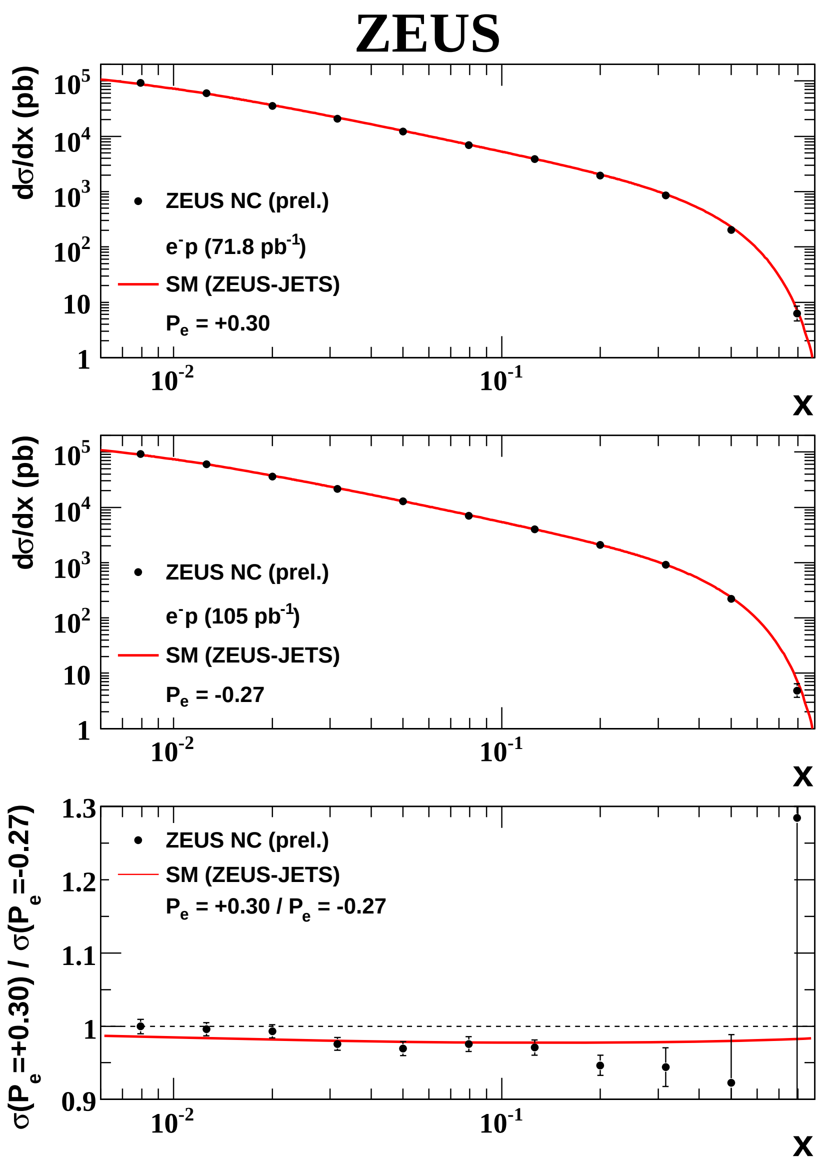
$$F_2(x, Q^2) = F_2^{\gamma} + P_e a_e \chi_Z F_2^{\gamma Z}$$

P^- (L) > P^+ (R) **(a_e = -0.5)**

Measured cross sections are in good agreement with SM predictions over whole kinematic region

Polarised NC results

-



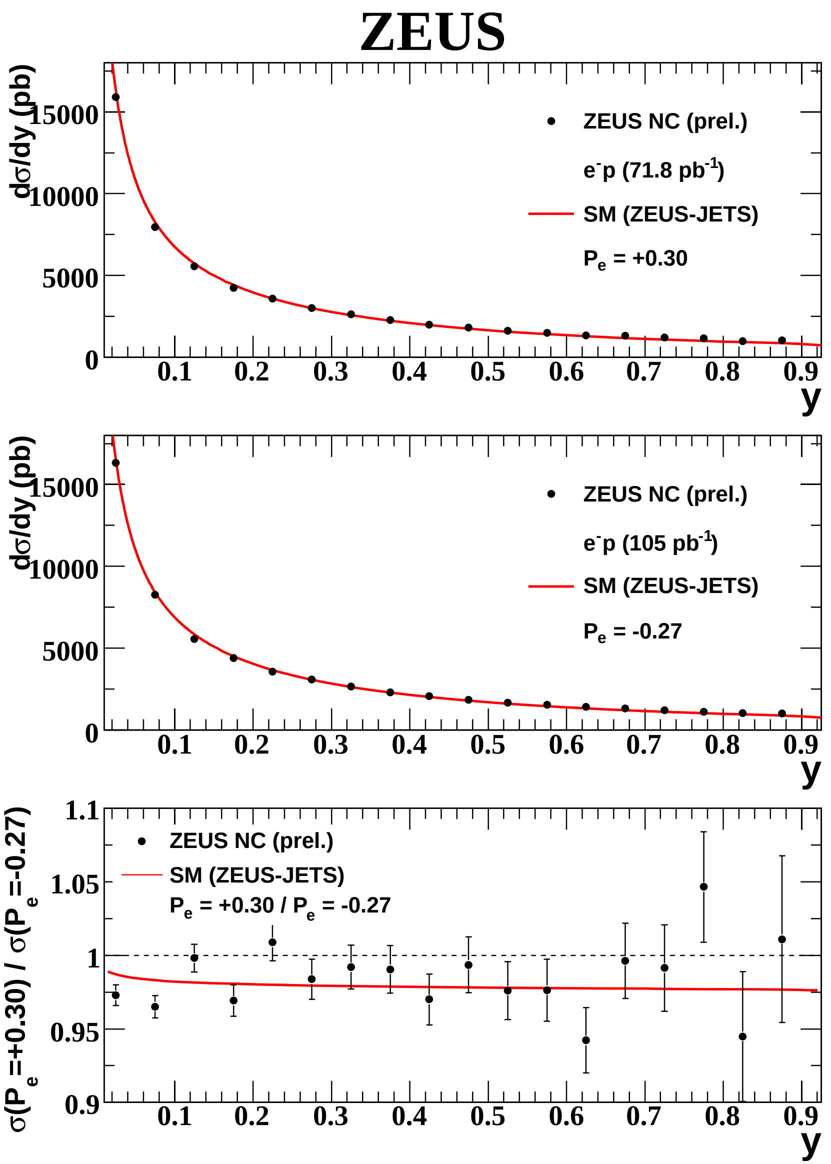
dσ/dx as a function of x:

PDF with QCD evolution matches data well over large range

Enhance difference with ratio +/-

SM prediction for the ratio +/- with polarisation included is favoured by data

Polarised NC results



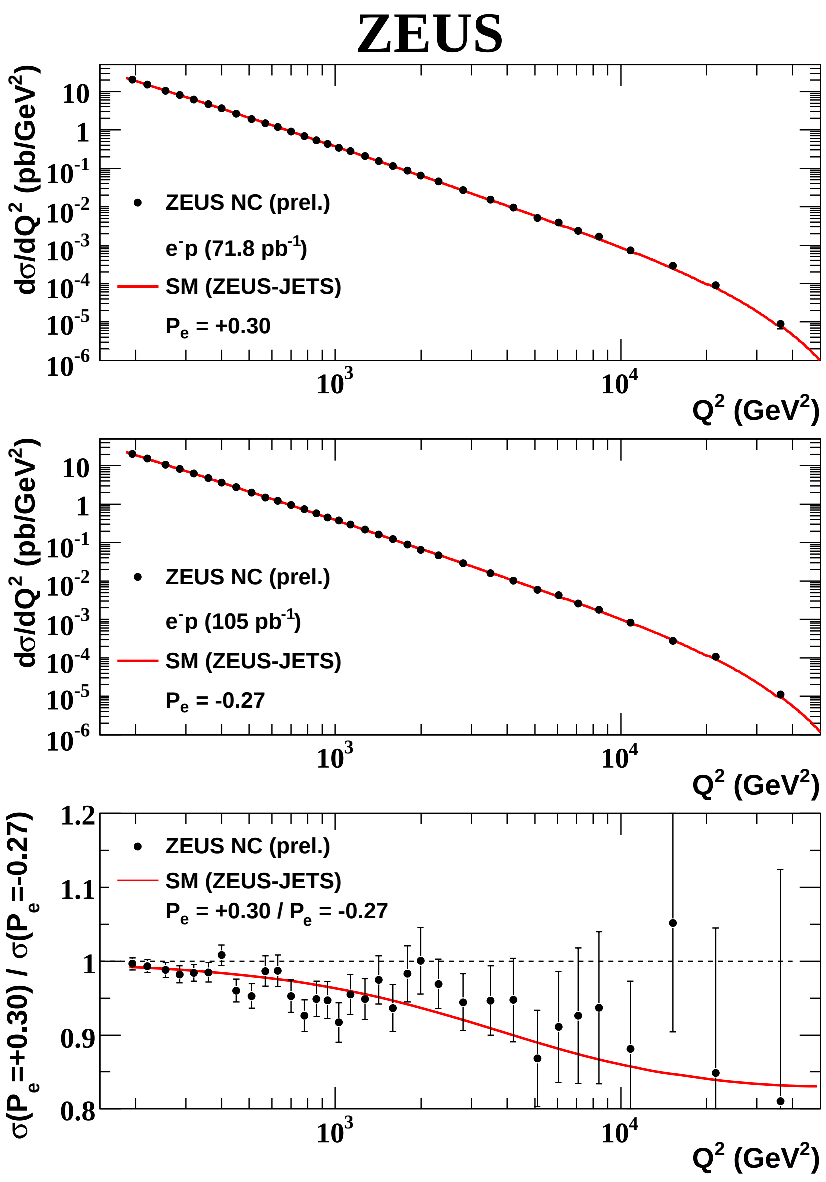
dσ/dy as a function of y:

PDF with QCD evolution matches data well over large range

Enhance difference with ratio +/-

Data matches theoretical prediction which includes polarisation

Polarised NC results



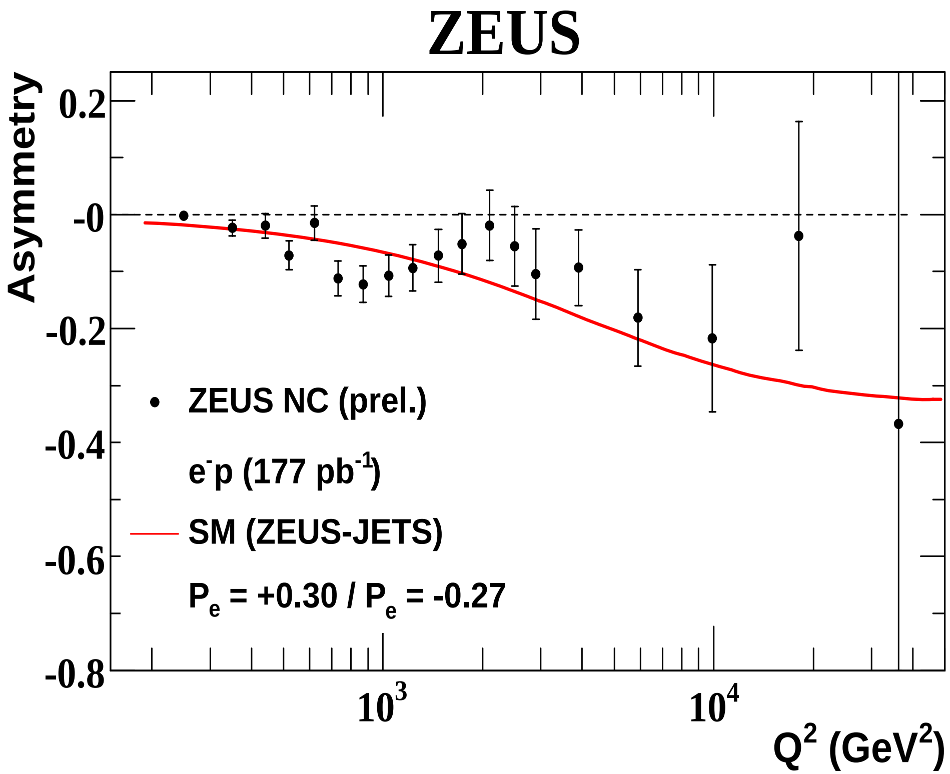
$d\sigma/dQ^2$ as a function of Q^2

for + (R) and – (L) polarised e^-

and the ratio +/-

Effect of parity violation in NC DIS clearly observed at the EW scale!

Asymmetry parameter A^-

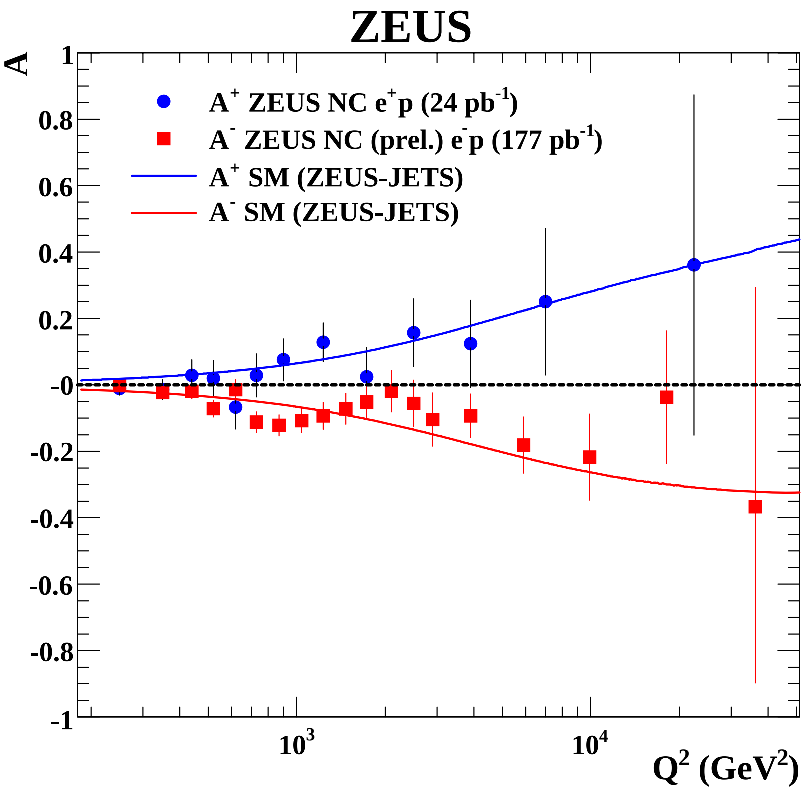


Directly see effect of parity violation due to $a_e v_q$ term!

Quantitative measure of the difference in the behaviour of R (+) and L (-) handed e^-

$$A^- = \frac{2}{P_e^+ - P_e^-} \cdot \frac{\sigma(P_e^+) - \sigma(P_e^-)}{\sigma(P_e^+) + \sigma(P_e^-)} \approx \chi_z a_e \frac{F_2^{\gamma Z}}{F_2^{\gamma}} \propto a_e v_q$$

Asymmetry parameter $A^{+/-}$ using only ZEUS data



Measured Asymmetries are consistent with the SM prediction for both

e+ → only 24 pb^{-1} .
10x more data available

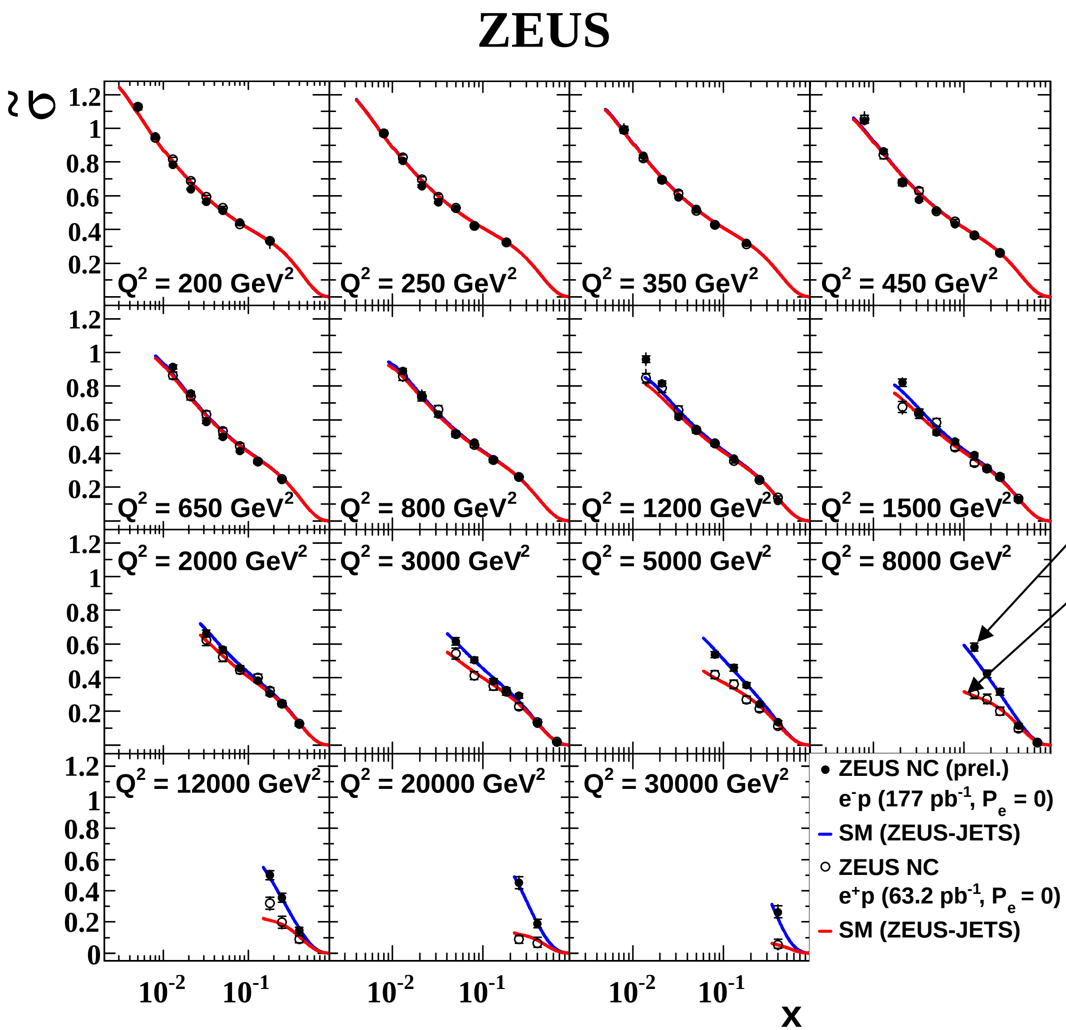
and

e-

A+ ~ -A-

$$A^{\pm} = \frac{2}{P_e^+ - P_e^-} \cdot \frac{\sigma^{\pm}(P_e^+) - \sigma^{\pm}(P_e^-)}{\sigma^{\pm}(P_e^+) + \sigma^{\pm}(P_e^-)} \approx \mp \chi_z a_e \frac{F_2^{\gamma Z}}{F_2^{\gamma}}$$

$$\tilde{\sigma}_{NC}^{\pm} = \frac{xQ^4}{2\pi\alpha^2}\frac{1}{Y_+}\frac{d^2\sigma_{NC}^{e^\pm p}}{dxdQ^2}$$



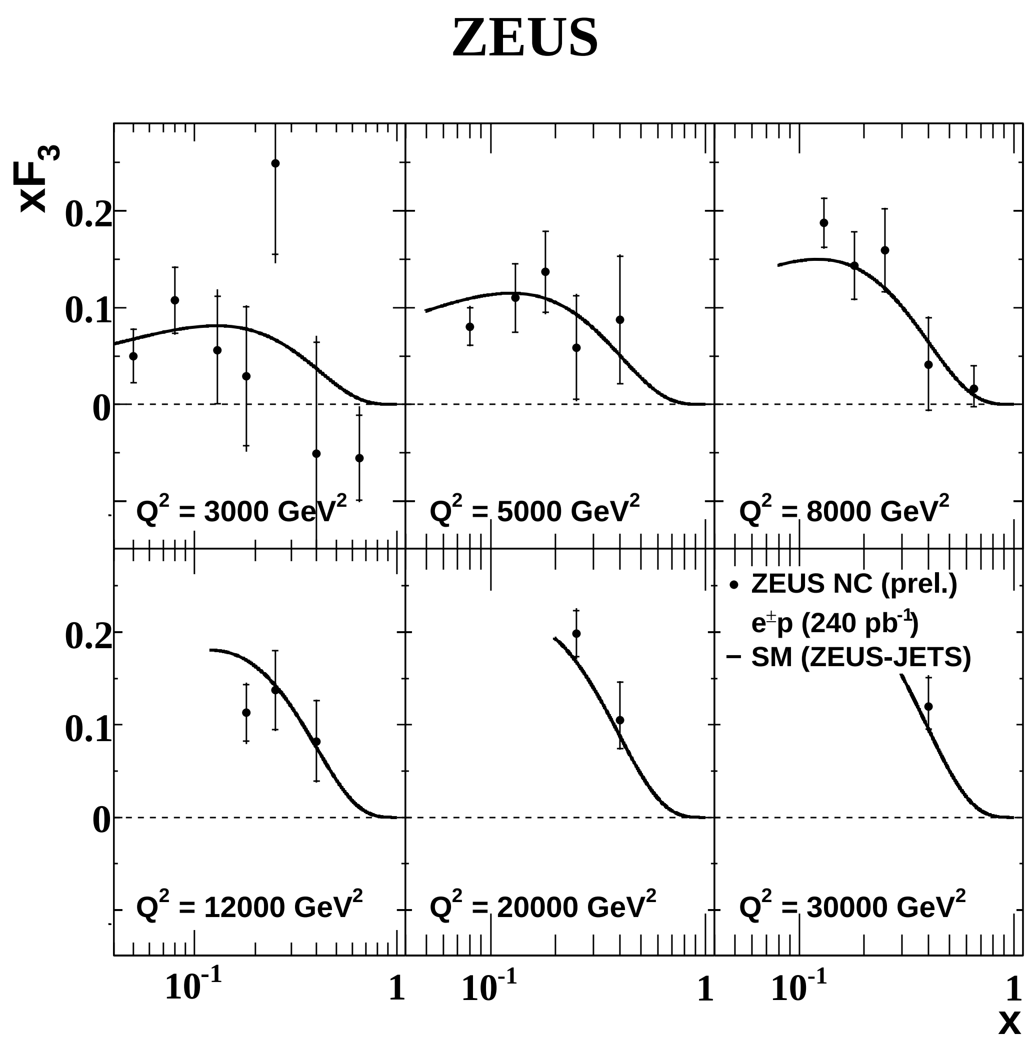
•Combine e (L+R) to extract "unpolarised" e^- p cross section

• Use HERA II "unpolarised" e^- p data with HERA I e^+p data:

*** Reduced cross section difference e^- p > e^+ p (see effect of sign)**

Measure xF_3 from this

$$xF_3 = \frac{Y_+}{2Y_-}\cdot(\tilde{\sigma}_{NC}^{e^-p} - \tilde{\sigma}_{NC}^{e^+p})$$



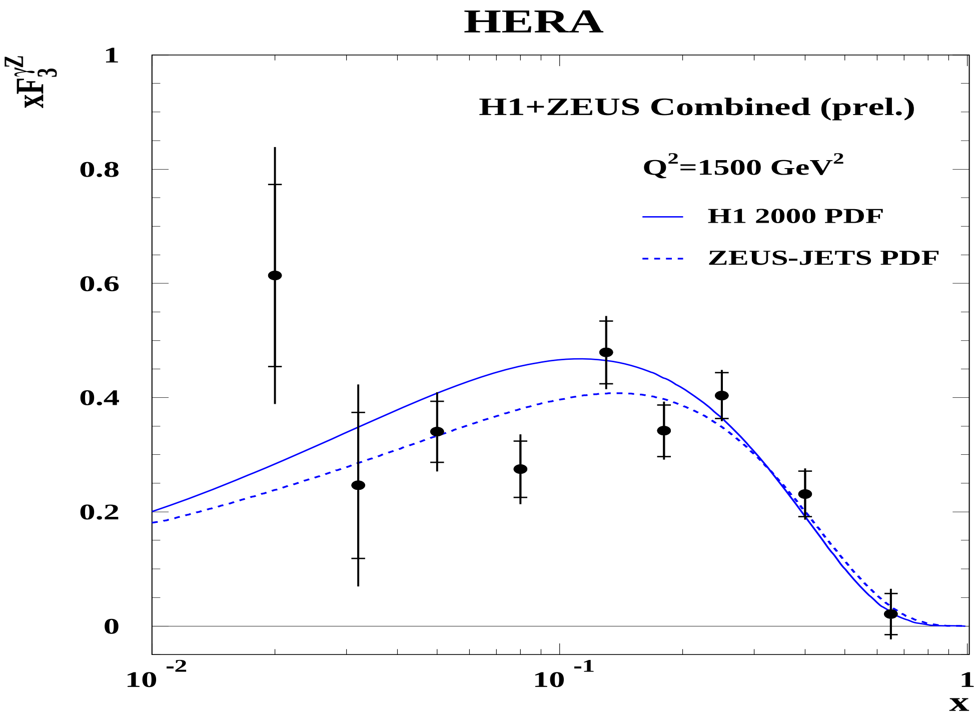
Most precise measurement of xF_3 from ep NC DIS at high Q^2

-Sensitivity to valence quark distribution in a region where there were no previous DIS measurements with pure proton target

Extract xF_3 for each bin
- can extract $xF_3^{\gamma Z}$

H1+ ZEUS data for ~ ½ total data set

$$xF_3(x,Q^2) \approx -a_e \chi_Z \, xF_3^{\gamma Z}$$



Extract xF_3 for each bin in Q^2 to obtain $xF_3^{\gamma z}$

- $xF_3^{\gamma z}$ weakly dependent on Q^2

- swim to one value of Q^2 e.g. 1500 GeV^2

-average over each x value for greater statistical significance

-sensitivity to valence distributions and can test sum rules

In QPM $$xF_3^{\gamma Z} = e_q a_q \sum_q 2x\left[q(x,Q^2) - \bar{q}(x,Q^2)\right]$$

Data from each experiment using total e+/ e- data and combined yet to come

Conclusions

HERA II

- High luminosity + Polarised leptons

Sensitivity to DIS @ EW scales using polarised leptons, for λ ~ 10^{-18} m.

Cross section Measurements for $e^{-\,(R/L)}$ p interactions

- **Reduced cross section**
- **Single differential cross sections – comparison with QCD fits**
- **Asymmetry A^-**
- **xF_3**
  - **Measurement of valence quark distribution**

To come …

Combined H1+ZEUS data for final polarised e^- p results with nearly $1fb^{-1}$ data